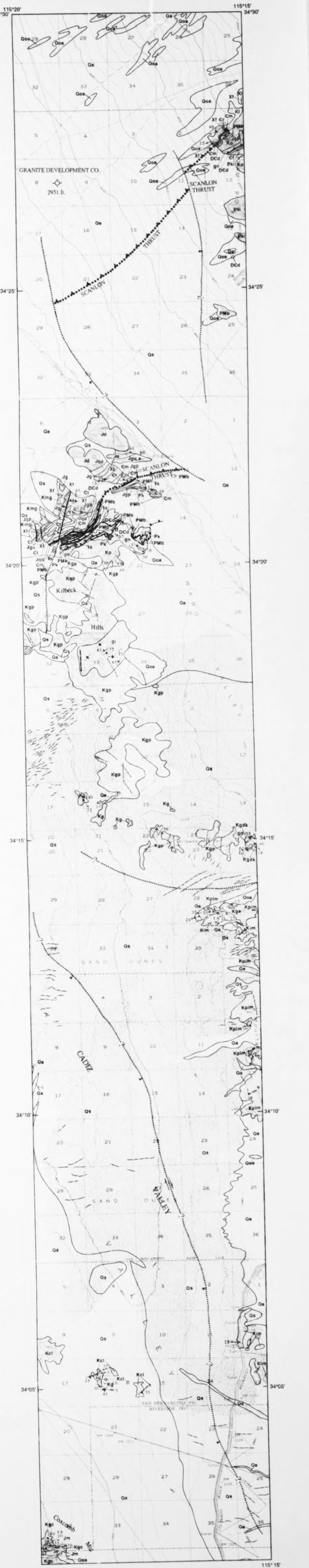
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

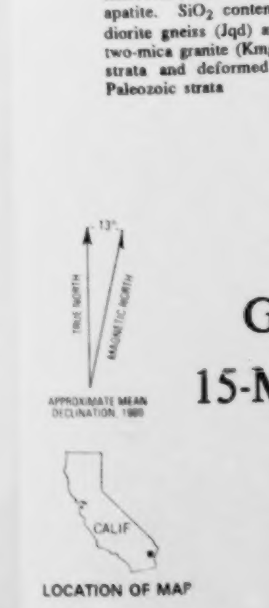


Base from U.S. Geological Survey, 1956
Polyconic projection

Geology mapped by K.A. Howard (1978-83), E.D. Horringa (1983-85), D.M. Miller (1979), P. Stone (1978-1979), and C.A. Allen (1982)
Manuscript approved for publication, April 4, 1989

SCALE 1:62 500

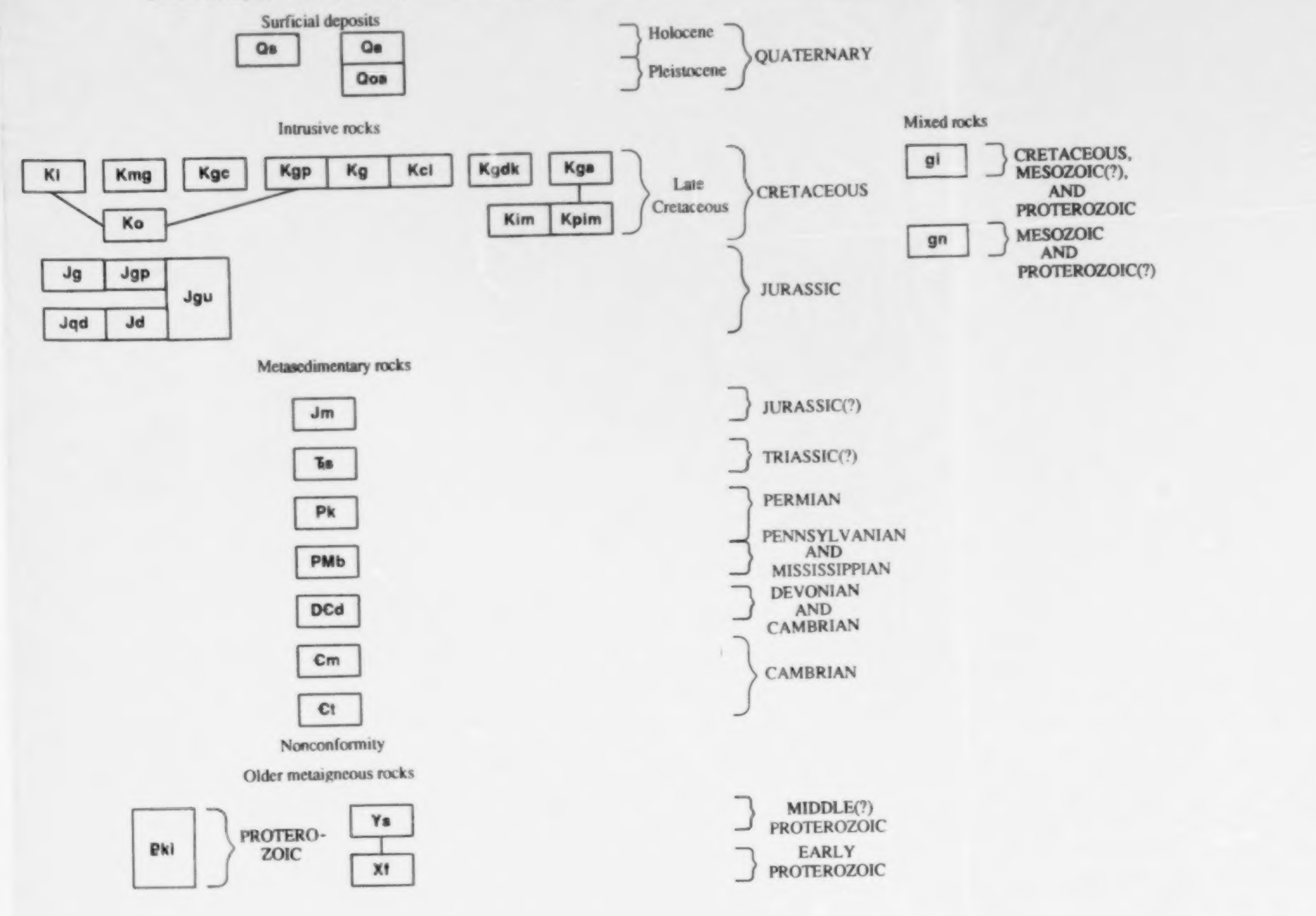
CONTOUR INTERVAL 80 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



MISCELLANEOUS FIELD STUDIES
MAP MF-2086

CORRELATION OF MAP UNITS

[Boxes are adjacent where units are gradational. A connecting line indicates observed intrusion of older rocks by younger rocks]



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qs **Windblown sand (Holocene)**--Well sorted sand. Includes sand sheets and low active and fossil dunes. Commonly banked against the northwest sides of hills. Contains pebble lag deposits in places

Qa **Alluvial fan deposits (Holocene)**--Poorly sorted sandy gravel, composed of locally derived subangular to angular clasts. May possibly be, in part, Pleistocene in age

Qoa **Older alluvium (Pleistocene)**--Poorly sorted sandy gravel, forming low dissected benches. Composed of locally derived subangular to angular clasts. Soil development is greater than for unit Qa. May possibly be, in part, Holocene in age

INTRUSIVE ROCKS

Kl **Leucogranite (Late Cretaceous)**--In the Old Woman Mountains. Lithologically equivalent rocks in the adjacent Milligan quadrangle are included with the leucogranite of Milligan by Howard and others (1989). White, medium-grained magnetite-biotite monzogranite, sparsely porphyritic. Mafic mineral content 4 modal percent. Contains allanite and sphene. SiO_2 content 75 percent (one sample). Has metamorphic texture and is lineated. Invades the projected position of the Scanlon thrust and may postdate it. Probably cuts the Old Woman Mountains Granodiorite. Small unmapped dikes cut the Fenner Gneiss in the northern Kilbeck Hills

Kmg **Two-mica granite (Late Cretaceous)**--In the northern Kilbeck Hills. Yellowish-gray-weathering, fine- to medium-grained, equigranular to seriate garnet-biotite-muscovite leucomonzogranite. Mafic mineral content 0.1 to 3 modal percent. Rock contains iron-titanium oxide, myrmekite, late crystallizing muscovite and microcline; one sample contains partly resorbed garnet and no biotite. SiO_2 content of two samples is 75 and 76 percent. Pegmatite is present at margins of intrusion and in dikes. Rarely foliated. Equivalent in lithology and structural position to two-mica granite of the Sweetwater Wash pluton 10 km northeast of the map area in the Old Woman Mountains; that pluton is dated at 70-75 Ma by U-Pb method on zircon and K-Ar method on biotite, and it is cross-cut by the 70-75-Ma Old Woman Mountains Granodiorite (Miller and others, in press)

Kgc **Porphyritic granodiorite in Coxcomb Mountains (Late Cretaceous)**--In southwest corner of map area. Mapped and described by Calzia and others (1983) as part of the Coxcomb Granodiorite of Miller (1944). Light-gray-weathering, medium-grained biotite granodiorite and monzogranite, generally containing 1-cm-long alkali feldspar phenocrysts. Mafic mineral content 4-10 modal percent. Contains oscillitory-zoned plagioclase, euhedral sphene, apatite, zircon, allanite. Closely resembles the porphyritic granodiorite in the Kilbeck Hills (Kgp), and probably represents a closely related pluton

Kgp **Porphyritic granodiorite in Kilbeck Hills (Late Cretaceous)**--Light-gray-weathering, medium-grained porphyritic biotite granodiorite. Alkali-feldspar phenocrysts 1 cm across generally abundant. Mafic mineral content is 5 to 13 modal percent. Biotite 0.5-1 mm. Euhedral sphene, iron-titanium oxide, apatite, zircon, and trace of allanite are present. Plagioclase is oscillatory zoned. Hypidiomorphic granular. SiO_2 content of three samples is 69 to 74 percent. Predominantly massive. Rocks at lat 34°15' are foliated, recrystallized, and contain 1.5-cm-long alkali-feldspar phenocrysts

Kg **Granite and granodiorite (Late Cretaceous)**--In the southern Kilbeck Hills, Cadiz Valley, and aplitic dikes (unmapped) in the Coxcomb Mountains. Very light gray weathering, medium-grained, equigranular biotite monzogranite and granodiorite. Mafic mineral content 2 to 13 modal percent. Biotite (subhedral and euhedral) 0.5-1 mm. Sphene, iron-titanium oxide, sparse muscovite, apatite, zircon, and trace euhedral allanite are present. Mylonitic foliation and lineation are present at lat 34°05' in southern Cadiz Valley

Kcl **Granodiorite of Cadiz Lake (Late Cretaceous)**--In southern Cadiz Valley. Light-gray-weathering, medium- to coarse-grained, porphyritic biotite granodiorite and monzogranite. Alkali feldspar phenocrysts, 2-3 cm across, contain zonal inclusions of plagioclase, sphene, and biotite. Phenocrysts are coarser than in other Cretaceous units. Mafic mineral content is 5-6 modal percent. Iron-titanium oxide, apatite, allanite, and as much as 1 percent sphene present. Contains secondary muscovite, chlorite, and (where mylonitic) epidote. Foliated, locally lineated; mylonite layers are present. The porphyritic texture and mylonitic structure are illustrated and discussed in Howard and others (1982, photograph fig. 3). Gradational to gneissic nonporphyritic granite of unit Kg

Kgdk **Porphyritic granodiorite of southeastern Kilbeck Hills (Late Cretaceous)**--Medium-light-gray-weathering, gneissic, medium-grained biotite granodiorite to quartz monzodiorite. Contains alkali-feldspar phenocrysts 1 to 2 cm long. Mafic mineral content about 9 modal percent. Darker and contains less quartz than nearby rocks of unit Kgp but is probably closely related. Contains iron-titanium oxide, apatite, zircon, euhedral allanite-epidote, and secondary muscovite and chlorite. SiO_2 content 68 percent (one sample)

Kga **Garnet aplite gneiss (Late Cretaceous)**--In the northern Iron Mountains. Leucocratic fine- to medium-grained garnet-muscovite-biotite syenogranite gneiss. Forms a deformed dike that cuts the porphyritic granodiorite gneiss of Iron Mountains (Kpim). Mylonitic foliation is perpendicular to the dike

Ko **Old Woman Mountains Granodiorite (Late Cretaceous)**--In the Old Woman Mountains and northern Kilbeck Hills. Medium-light-gray-weathering sphene-hornblende-biotite granodiorite. Medium grained, equigranular, hypidiomorphic granular. Contains igneous foliation in the Kilbeck Hills and metamorphic foliation in the Old Woman Mountains. Rare alkali-feldspar phenocrysts. Euhedral sphene is conspicuous in hand specimen. Mafic mineral content 14 to 19 modal percent. Plagioclase shows oscillatory zoning. Iron-titanium oxide and trace amounts of apatite, zircon, and allanite are present. Euhedral epidote of probable magmatic origin is present in the Old Woman Mountains. SiO_2 content 64-65 percent for two samples from the Kilbeck Hills. Dated by U-Pb method on zircon as about 71 Ma in the Old Woman Mountains 11 km east of the map area (Miller and others, in press). Intrudes the dark gneiss unit (gn). Cut by and possibly gradational with the porphyritic granodiorite in the Kilbeck Hills (Kgp). Forms the Old Woman pluton, exposed mainly in the adjacent Milligan quadrangle east of the map area (Miller, Howard, and Hoisch, 1982; Howard and others, 1989)

Kim **Granite gneiss of Iron Mountains (Late Cretaceous)**--Leucocratic muscovite-biotite monzogranite mylonitic gneiss. Commonly cut by aplite and pegmatite dikes. Subequigranular, fine to medium grained. Mafic mineral content 3 to 9 modal percent. Contains iron-titanium oxide, apatite, zircon; locally contains garnet. SiO_2 content 72 and 73 percent in two samples. Rocks in northern exposure (lat 34°13') are the more mafic and are gradational to porphyritic unit Kpim. Some rocks of unit Kim intrude unit Kpim in the adjacent Iron Mountains quadrangle. Dating of biotite (from exposure at lat 39°06') by the K-Ar technique gave 65 Ma, and dating of biotite and whole rock by the Rb-Sr technique gave 61 Ma (W.A. Rehrig, in Miller and others, 1981). Lineated surfaces called "hot slickensides" are steeper than foliation; the lineations strike parallel to mylonitic lineation

Kpim **Porphyritic granodiorite gneiss of Iron Mountains (Late Cretaceous)**--Brownish-gray-weathering muscovite-biotite granodiorite and monzogranite gneiss. Commonly cut by aplite and pegmatite dikes. Contains zoned 1-cm-long alkali-feldspar augen porphyroclasts in a fine- to medium-grained mylonitic matrix. Mafic mineral content is 5 to 8 modal percent. Contains iron-titanium oxide, epidote, zircon, and apatite. SiO_2 content 74 percent (one sample). East of the map area, the U-Pb age on zircon is 70-73 Ma (Wright and others, 1987)

Jg **Granite gneiss (Jurassic)**--In the northern Kilbeck Hills. Light-gray-weathering, fine-grained, seriate biotite monzogranite and monzogranite gneiss. Mafic mineral content is 4 to 8 modal percent. Contains iron-titanium oxide and small amounts of muscovite, zircon (with pleochroic halos in biotite), allanite, and apatite. SiO_2 content 73 percent (one sample). Cuts the quartz diorite gneiss (Jqd) and the Fenner Gneiss (Xf), and is cut by the two-mica granite (Kmg). Deformed into gneiss where near Paleozoic strata and deformed into dark fissile gneiss where diked into Paleozoic strata

Jgp **Porphyritic granite gneiss (Jurassic)**--In the northern Kilbeck Hills and the Old Woman Mountains. Brownish-gray weathering biotite monzogranite and granodiorite gneiss. Roundish to rectangular, very light gray to pale-pink, 1-cm-long augen phenocrysts and porphyroclasts of alkali feldspar and plagioclase, commonly recrystallized to quartz + feldspar, are in a dark, medium-grained to very fine grained, foliated matrix, commonly showing metamorphic textures indicative of annealing. Contains mafic microgranitoid enclaves about 2 cm across. Mafic mineral content is 8 to 15 modal percent. Contains iron-titanium oxide, sphene, rare euhedral epidote, local hornblende, and local metamorphic muscovite. SiO_2 content 66 and 72 percent on two samples. Gradational into the granite gneiss (Jg). Cuts the quartz diorite gneiss (Jqd), the Fenner Gneiss (Xf), and Paleozoic strata, and is cut by the two-mica granite (Kmg) and the Old Woman Mountains Granodiorite (Ko)

Jqd **Quartz diorite gneiss (Jurassic)**--In the northern Kilbeck Hills. Dark-weathering, medium-grained hornblende-biotite gneiss of quartz diorite, granodiorite, diorite, and quartz monzodiorite composition. Mafic mineral content is 20 to 40 modal percent. Xenoblastic texture shows evidence of annealing. Contains 1 percent or more each sphene and iron-titanium oxide. SiO_2 content 54 and 55 percent (two samples). Cuts the Fenner Gneiss and Paleozoic units, and is cut by units Jg and Jgp. U-Pb concordant age on zircon is about 162 Ma (J.E. Wright, written commun., 1986)

Jd **Diorite (Jurassic)**-- In the northern Kilbeck Hills. Dark-gray, medium-grained hornblende and hornblende-clinopyroxene diorite and gabbro. Commonly recrystallized but shows gabbroic igneous protolith texture. Mafic mineral content 20 to 50 modal percent. Contains sphene, iron-titanium oxide, epidote, late-crystallizing igneous apatite. SiO_2 content 51 percent (one sample). Contains calc-silicate inclusions probably derived from Paleozoic strata

Jgu **Gneissic granitoid rocks, undivided (Jurassic)**--Units Jg, Jgp, Jqd, and Jd, where they are not mapped separately

METASEDIMENTARY ROCKS

Jm **Metasedimentary rocks (Jurassic?)**--In the Coxcomb Mountains. Phyllite, hornfels, calc-silicate granofels, quartzitic phyllite, and fine-grained amphibolite. Calzia and others (1983) considered the unit as part of the McCoy Mountains Formation of Miller (1944). Mineral assemblages include garnet-muscovite-biotite (Calzia and others, 1983), plagioclase-tremolite-diopside, and epidote-hedenbergite-quartz-plagioclase. Intruded by unit Kgc and by an unmapped, older metamorphosed biotite-hornblende quartz diorite to quartz monzodiorite gneiss (mafic content 20 to 30 percent) that may be equivalent to a Jurassic granitoid recognized a few kilometers west of the map area (Calzia and others, 1983)

TRs **Schist and gneiss (Triassic?)**--Dark-gray fissile gneiss and schist. Overlies the metamorphosed Kaibab Limestone. Lower part consists of epidote-bearing feldspathic mica schist and gneiss. Upper part consists of feldspathic garnet-two-mica schist and gneiss and includes sillimanite-mica schist. May correlate with clastic rocks of the Buckskin Formation of Reynolds and others (1988) in western Arizona and with Triassic strata elsewhere in southeastern California described by Stone and others (1983) and Walker (1987)

Pk **Metamorphosed Kaibab, Coconino, and Hermit Formations, undivided (Permian)**--The metamorphosed Kaibab Limestone consists of gray and white dolomitic calcitic marble. The underlying metamorphosed Coconino Sandstone consists of fine-grained metaquartzite. The underlying metamorphosed Hermit Shale consists of calc-schist; it overlies the metamorphosed Bird Spring Formation

PMb **Metamorphosed Bird Spring Formation (Permian and Pennsylvanian) and Redwall Limestone (Mississippian)**--The metamorphosed Bird Spring Formation consists of layered marble, dusky-brown-weathering quartzitic marble, and thin vitreous metaquartzite. Contains diopside. In lower thrust sheets of the Kilbeck Hills, the metamorphosed Bird Spring is partly dusky-brown-weathering wollastonite marble and wollastonite rock. The underlying metamorphosed Redwall Limestone consists of medium- to coarse-grained, white calcitic marble containing dusky-brown siliceous metachert lensoid layers a few centimeters thick. The metamorphosed Redwall overlies the dolomite marble unit

D€d **Dolomite marble (Devonian and Cambrian)**--Greenish-yellow, massive to bedded dolomite marble. Inferred to correlate with the Sultan and Nopah Formations and upper part of the Bonanza King Formation. Overlies the banded marble unit

€m **Banded marble (Cambrian)**--Gray and white, laminated to mottled calcitic marble. Correlated with the Muav Limestone and the lower part of the Bonanza King Formation. Overlies the Bright Angel Shale

€t **Metamorphosed Tapeats Sandstone and Bright Angel Shale, undivided (Cambrian)**--The metamorphosed Bright Angel consists of muscovite-biotite and sillimanite-muscovite-biotite schist in both the Kilbeck Hills and the Old Woman Mountains. The underlying metamorphosed Tapeats consists of an upper part of white to yellowish-gray metaquartzite, considered equivalent to the Zabriskie Quartzite, and a lower part of brown, crossbedded, arkosic, partly conglomeratic metaquartzite, considered equivalent to the Wood Canyon Formation. The Tapeats rests nonconformably on the Fenner Gneiss (Xf) and probably on the Kilbeck Gneiss (Bki)

OLDER METAIGNEOUS ROCKS

Bki **Kilbeck Gneiss (Proterozoic protolith age)**--In the Old Woman Mountains. Medium-grained biotite monzogranite gneiss characterized by wispy foliation consisting of dark mafic stripes and light-colored quartzofeldspathic stripes. Mafic mineral content about 10 modal percent

Ys **Syenogranite (Middle? Proterozoic)**--Mapped only at one locality in the northern Kilbeck Hills (SW1/4NW1/4 sec. 16, T. 3 N., R. 16 E.). Well-foliated, coarse-grained, quartz-rich leucocratic syenogranite characterized by tabular to lensoid 1- to 2-cm-long megacrysts of microcline. Contains biotite and some muscovite, iron-titanium oxide, and zircon (with pleochroic halos in biotite). Intrudes the Fenner Gneiss

Xf **Fenner Gneiss (Early Proterozoic)**--In the northern Kilbeck Hills and Old Woman Mountains. Unit originally introduced by Hazzard and Dosch (1937) (also called the Fenner Granite Gneiss). Dark biotite-rich augen gneiss of monzogranite, granodiorite, and quartz monzodiorite composition. Characterized by very coarse grained, white, blocky alkali feldspar megacrysts 1 to 6 cm across in a biotite-rich matrix. Mafic mineral content is 11 to 20 modal percent. Contains iron-titanium oxide, apatite, zircon, and locally muscovite. Megacrysts are generally recrystallized to quartz + feldspar and are in places deformed to rod shapes. SiO_2 content 64 percent (one sample of quartz monzodiorite). Includes layers and bodies of biotite-hornblende quartz diorite gneiss. Dated by U-Pb method on zircon at about 1.67-1.70 Ga in the Kilbeck Hills (L.T. Silver, oral commun., 1982)

MIXED ROCKS

gi **Granite intrusive into gneiss (Cretaceous, Mesozoic?, and Proterozoic)**--In the central Kilbeck Hills. Predominantly granite and gneiss. Composed of augen gneiss (Bki or Xf), dark gneiss (gn?), and amphibolite, all intimately intruded by granite and granodiorite associated with units Kpg and Kg

gn **Dark gneiss (Mesozoic and Proterozoic?)**--In the Kilbeck Hills and Old Woman Mountains. Highly foliated, medium-dark-gray to medium-gray gneiss, intruded by units Ko and Kgdk. Largely quartzofeldspathic biotite gneiss. In the northern Kilbeck Hills includes, among other rock types, rocks lithologically identical to the Jurassic porphyritic granite gneiss (Jgp) and biotite-muscovite-quartz schist. The latter rock type is probably a paraschist; two analyzed samples consisted of the following (in percent; analyzed by J. Ardith, F. Bartel, J. Stewart, J. Taggart, and L. Espos, U.S. Geological Survey): Sample H83Ki-29--SiO_2 (72.8), Al_2O_3 (13.3), FeO (1.33), Fe_2O_3 (0.47), MgO (0.74), CaO (0.73), Na_2O (2.38), K_2O (6.33), TiO_2 (0.67), P_2O_5 (0.09), MnO (0.02), H_2O+ (0.41), H_2O- (0.05), CO_2 (0.13); sample H83Ki-30--SiO_2 (78.9), Al_2O_3 (10.0), FeO (1.36), Fe_2O_3 (1.60), MgO (0.88), CaO (0.45), Na_2O (1.79), K_2O (2.25), TiO_2 (0.67), P_2O_5 (0.09), MnO (0.02), H_2O+ (1.14), H_2O- (0.09), CO_2 (0.12). The unit is interpreted as a tectonic schist (Hutton, 1979) of heterogeneous protolith

Contact

Fracture lineament

Tectonic slide (ductile thrust or lag fault)--Teeth on upper plate. Dotted where concealed. Heavy line indicates the slide interpreted as the Scanlon thrust

Normal or oblique slip fault--Showing dip. Dashed where inferred; dotted where concealed; queried where inferred from aeromagnetic and gravity data. Bar and ball on downthrown side. Arrows show strike or oblique slip

Foliation--Showing strike and dip

- Metamorphic-Inclined
- Metamorphic-Vertical
- Igneous-Inclined
- Igneous-Vertical

Lineation--Showing trend and plunge. May be combined with foliation symbols

- Mylonitic
- Nonmylonitic or annealed

Fold axis

Mineralized joints--Showing strike and dip. Surfaces exhibit white mica and hematite

Crest of sand dunes--Mapped from aerial photographs taken in 1973 and 1975

Test hole drilled for oil or gas--Abandoned. Depth in feet indicated

ABANDONED TEST HOLE DRILLED FOR OIL OR GAS

Mojave No. 1, sec. 8, T. 4 N., R. 16 E. Drilled and abandoned by Granite Development Company in 1979. Summary driller's log reported that the sediments from top to total depth (2951 ft) are granite-wash alluvium varying from coarse to very coarse grained; finer grained with depth. A few beds of fine-grained subrounded sand were encountered. At 1450 ft the beds became clayey, but clay then decreased downward. Only fresh water was encountered in the hole.

INTRODUCTION

This map covers a strip in the Mojave Desert that fills a gap between other published geologic maps (fig. 1). The map area includes parts of Cadiz and Ward Valleys, the Kilbeck Hills (north-central part of the map), and parts of the Iron Mountains (southeast part of the map), Old Woman Mountains (northeast part of map), and Coxcomb Mountains (southwest corner of the map). Previous geologic maps covering parts of the area can be found in Danehy and Collier (1959), Spurk (1959a, b), Kupfer and Bassett (1962), Bishop (1963), Moyle (1967), Evenson (1973), Jones (1973), Davis and Kuniyoshi (1974), Calzia and others (1983), Stone and others (1983), and Brown (1984). An earlier version of the present map was included as a base for gravity and aeromagnetic maps of the region (Simpson and others, 1984). The present map is modified to incorporate the results of 1:6,000-scale geologic mapping by Horringa (1986) of the northern Kilbeck Hills.

GEOLOGIC SUMMARY

PRE-QUATERNARY ROCKS

Two Proterozoic orthogneiss units crop out that are more widely exposed east and northeast of the map area--the Fenner Gneiss and the Kilbeck Gneiss (Hazzard and Dosch, 1937; Miller, Howard, and Hoisch, 1982; Bender and Miller, 1987; Howard and others, 1989). Figure 2 indicates modal compositions of the Fenner and many other plutonic units. A small exposure of gneissic syenogranite (Ys) that intrudes the Early Proterozoic Fenner resembles Middle Proterozoic rocks described elsewhere in southeastern California by Anderson (in press). The Proterozoic rocks together represent a basement overlain nonconformably by a sequence of Paleozoic and Triassic(?) strata.

These strata are correlated on the basis of lithologic sequence to a regional sequence of shallow-water marine formations (Stone and others, 1983). The stratified Paleozoic and Triassic(?) units are metamorphosed, tectonized, and attenuated and in places are too thin to show on the map. Contacts between them are nearly all parallel to layering, and conformable contacts can be distinguished from tectonic ones only on the basis of whether the sequence is stratigraphically correct or disrupted.

Metasedimentary rocks (Jm) studied by Calzia and others (1983) at the southwest corner of the map area are tentatively correlated to part of the McCoy Mountains Formation of Harding and Coney (1985) and are assigned a Jurassic(?) age; J.P. Calzia (unpub. data, 1983; Calzia and others, 1983) has established that in this map area those rocks are intruded by now-metamorphosed plutonic rocks that resemble Jurassic protoliths west of the map area. Elsewhere, part of the McCoy Mountains Formation is Cretaceous in age (Stone and others, 1987). A diverse suite of Jurassic metaplutonic rocks, for which counterpart rocks are present in ranges to the west of the area (Miller, Howard, and John, 1982; Howard and John, 1984), crops out in the Kilbeck Hills.

Late Cretaceous granite and granodiorite compose most of the pre-Quaternary rocks in the map area. The two-mica granite (Kmg) and the Old Woman Mountains Granodiorite (Ko) are more widely exposed east of the map area in the Old Woman Mountains, where they have been grouped as the Old Woman-Piute composite batholith and characterized isotopically and chemically by Miller, Howard, and Hoisch (1982) and Miller and others (in press). The leucogranite (Kl) probably correlates with the leucogranite of Milligan mapped in the Milligan quadrangle (Howard and others, 1989). The other mapped Late Cretaceous plutonic rocks, which form several plutons, have been included both as part of the Coxcomb Granodiorite of Miller (1944; Calzia, 1982; Calzia and others, 1983) and (or) as part of the Cadiz Valley batholith (John, 1981; Miller, Howard, and John, 1982; Howard and John, 1984). The rocks in the Iron Mountains are highly deformed (Miller and Howard, 1985). Outside the map area, U-Pb dating on zircon of some of the Late Cretaceous units (Kpim, Kmg, Ko) and closely related units establishes that they are all about 70-73 Ma (Wright and others, 1987; Calzia and others, 1986). Unit Kgp of the Cadiz Valley batholith intrudes the Old Woman Mountains Granodiorite (Ko) in the Kilbeck Hills.

STRUCTURE

Proterozoic, Paleozoic, Triassic(?), and Jurassic rocks in the northern Kilbeck Hills and Old Woman Mountains are metamorphosed, foliated, and deformed in a northeast-trending zone of ductile thrust faulting and folding. Amphibolite metamorphic grade for the pre-Late Cretaceous rocks is indicated by sillimanite in the metamorphosed Bright Angel Shale in the Kilbeck Hills and Old Woman Mountains and diopside in Paleozoic calc-silicate rocks in the Kilbeck Hills; diopside is present also in the Jurassic(?) metasedimentary rocks in the Coxcomb Mountains. The thrust zone extends northeast of the map area through and beyond the Old Woman Mountains (Miller, Howard, and Hoisch, 1982; Howard and others, 1987, 1989). A distinctive structural sequence in the Kilbeck Hills typifies much of the 45-km length of this structural zone and its environs. The structural sequence dips northwest and consists, in ascending order, of (1) the Late Cretaceous Old Woman Mountains Granodiorite, (2) the dark gneiss, (3) mostly upright upper (and some lower) Paleozoic and Triassic strata, (4) a thrust fault, (5) inverted lower Paleozoic strata and their inverted Proterozoic basement rocks, and (6) Late Cretaceous two-mica granite that intrudes the Proterozoic rocks. This sequence contains several tectonic slides--a term applied to ductile, concordant synmetamorphic or premetamorphic faults in a zone of penetrative deformation (Bailey, 1910; Hutton, 1979). The Late Cretaceous two-mica granite and the Old Woman Mountains Granodiorite, although they follow consistent positions in the structural sequence, cut the slides and the ductilely deformed rocks. The granodiorite is itself locally deformed.

In the Old Woman Mountains northeast of the map area, the name Scanlon thrust is applied to the prominent tectonic slide (4) that juxtaposes the inverted Proterozoic and lower Paleozoic hanging-wall rocks above the upright upper Paleozoic strata and Triassic footwall rocks (Howard and others, 1987). The comparable structure in the Kilbeck Hills is here also proposed as the Scanlon thrust. It is one of the highest of the tectonic slides. In the Kilbeck Hills some of the other nearby slides have nearly coequal stratigraphic throw.

An aeromagnetic low, north of a high, tracks near the Scanlon thrust both in the Kilbeck Hills and northeast of the map area in the Old Woman Mountains (U.S. Geological Survey 1981; Simpson and others, 1984). The aeromagnetic gradient may represent the southern boundary of nonmagnetic Late Cretaceous two-mica granite against the more magnetic Fenner Gneiss, mafic Jurassic rocks, and Late Cretaceous Old Woman Mountains Granodiorite. A corresponding aeromagnetic gradient provides a basis for mapping the inferred concealed Scanlon thrust in lowlands 5 to 8 km north of the Kilbeck Hills. The aeromagnetic low here may in part be due to thick alluvial fill, which is at least 2,951 ft (900 m) thick at the drill hole shown on the map.

The Jurassic plutonic rocks in the Kilbeck Hills are metamorphosed and foliated parallel to the slides. Tectonic plates in the Kilbeck Hills above and below the Scanlon thrust and the plate composed of the dark gneiss unit at the base of the zone of sliding contain some of the deformed, premetamorphic, porphyritic granite gneiss (Jurassic), which suggests that either the slides partly predate the porphyritic granite gneiss, the protolith was regionally widespread, or offsets on the slides in the Kilbeck Hills are small. The dark gneiss unit at the base of the zone of sliding is highly strained, lithologically heterogeneous, and stratigraphically out of place as evidenced by paraschist of unknown (but not Paleozoic) protolith age juxtaposed out of sequence against Paleozoic formations. The dark gneiss unit consistently is in a structural position below Paleozoic strata and above the postsliding Old Woman Mountains Granodiorite over a strike length of 45 km (Howard and others, 1987). These characteristics suggest its origin as an allochthonous tectonic schist (see Hutton, 1979) formed in a zone of high strain.

Mylonitic foliation and lineation overprint some of the Late Cretaceous plutonic rocks, particularly in the Iron Mountains. Miller and others (1981), Howard and others (1982), and Miller and Howard (1985) discussed the character of the mylonitic deformation in the Iron Mountains, reported K-Ar and Rb-Sr isotopic evidence for a latest Cretaceous age, and interpreted the deformation as related to pluton emplacement.

Surficial deposits conceal several postplutonic faults in the map area. Inferred positions of these faults were mapped using a combination of geologic, aeromagnetic, and gravity data. A concealed east-striking fault, coincident with an aeromagnetic low, juxtaposes granodiorite in the Kilbeck Hills against mylonitic granite and granodiorite units in the Iron Mountains. Late Cretaceous metamorphic lineations south of the fault (in the Iron, Granite, Coxcomb, and Sheep Hole Mountains) strike southwest-northeast, whereas those north of the fault in the Kilbeck Hills and in the Old Woman Mountains to the east strike mainly southeast-northwest. This contrast in regional trends of Late Cretaceous metamorphic lineations across the fault suggest that the fault may be regionally important.

Two faults striking approximately north beneath Ward Valley are inferred in order to explain (1) the apparent left-lateral separation, from the Kilbeck Hills to the Old Woman Mountains, of the structural sequence that includes the Scanlon thrust, (2) similar separation of the aeromagnetic gradient associated with this sequence, (3) greater attenuation of units and probably higher metamorphic grade in the Old Woman Mountains than in the Kilbeck Hills, (4) slightly younger Late Cretaceous K-Ar mica cooling ages in the Kilbeck Hills than in the Old Woman Mountains (Miller, Howard, and Hoisch, 1982), and (5) aeromagnetic and gravity gradients (Simpson and others, 1984) that suggest steps in the buried bedrock surface. Reasons (3) and (4) suggest that rocks in the Kilbeck Hills represent a higher structural level that was downdropped from rocks to the east in the Old Woman Mountains. This down-to-west sense of offset for the buried faults agrees with the sense on the mapped faults in the Kilbeck Hills, on faults in the Old Woman Mountains east of the map area (Howard and others, 1989), and on a Miocene normal fault system on strike a few kilometers north of the map area between the Ship and Old Woman Mountains (Knoll, 1985; Knoll and others, 1986).

Cadiz Valley is inferred to be a right-oblique pull-apart graben. A graben structure is inferred from gravity and aeromagnetic data (Simpson and others, 1984) and seismic-reflection profiling (D.A. Okaya and E.G. Frost, unpublished data, 1987). A steep north margin of the Cretaceous Cadiz Valley batholith, represented on this map by the north contact of unit Kgp, shows a possible 8-km right separation across Cadiz Valley to the Calumet Mountains 20 km west of the map area (Howard and John, 1984). A right-slip sense, while not compelling, is consistent with other regional geologic data. Consequently a right-oblique concealed fault is mapped in Cadiz Valley. The inferred fault is positioned where gravity and magnetic gradients are present (Simpson and others, 1984).

REFERENCES CITED

Anderson, J.L., in press, Proterozoic anorogenic granites of the southwestern U.S.: Arizona Geological Society Digest, v. 17.

Bailey, E.B., 1910, Recumbent folds in the schists of the Scottish Highlands: Geological Society London Quarterly Journal, v. 66, p. 586-608.

Bender, E.E. and Miller, C.F., 1987, Petrology of the Fenner Gneiss, a major Proterozoic metaplutonic unit in the eastern Mojave Desert, Calif.: Geological Society of America Abstracts with programs, v. 19, p. 358.

Bishop, C.C., 1963, Geologic Map of the Needles Sheet: California Division of Mines and Geology, Geologic Map of California, Olaf P. Jenkins Edition, scale 1:250,000.

Brown, H.J., 1984, Correlation of metamorphosed Paleozoic strata of the southeastern Mojave Desert region, California and Arizona: Discusssion: Geological Society of America Bulletin, v. 95, p. 1482-1485.

Calzia, J.P., 1982, Geology of granodiorite in the Coxcomb Mountains, southeastern California, in Frost, E.G., and Martin, D.M., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada (Anderson-Hamilton volume): San Diego, Calif., Cordilleran Publishers, p. 173-180.

Calzia, J.P., DeWitt, Ed, and Nakata, J.K., 1986, U-Th-Pb age and initial strontium isotopic ratios of the Coxcomb Granodiorite and a K-Ar age of olivine basalt from the Coxcomb Mountains, southern California: Isochron/West, no. 47, p. 3-8.

Calzia, J.P., Kilburn, J.E., Simpson, R.W., Jr., Allen, C.M., Leszcykowski, A.M., and Causey, J.D., 1983, Mineral resource potential map of the Coxcomb Mountains Wilderness Study Area (CDCA-328), San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1603-A, scale 1:62,500.

Danehy, E.A., and Collier, J.T., 1959, Geology and mineral resources of Township 3 North, Ranges 15 and 16 East, San Bernadino Meridian, San Bernardino County, California: San Francisco, Calif., Southern Pacific Land Coumpany, unpublished map and report, scale 1:24,000.

Davis, G.A., and Kuniyoshi, S., 1974, Geologic map of the Kilbeck Hills-western Old Woman Mountains area, Needles Map Sheet, California, in Woodward-McNeill and Associates, in Southern California Edison Company, Information concerning site characteristics, Vidal Nuclear Generating Station, Vol. V, Appendix 2.5-E, fig. E-9, scale 1:20,560 (approx.).

Evenson, W.A., 1973, Geology of the southern Kilbeck Hills and an adjacent portion of the Old Woman Mountains, eastern Mojave Desert, San Bernardino County, California: Los Angeles, Calif., University of Southern California, M.S. thesis.

Harding, L.E. and Coney, P.H., 1985, The geology of the McCoy Mountains Formation, southeastern California and southwestern Arizona: Geological Society of America Bulletin, v. 96, p. 755-769.

Hazzard, J.C. and Dosch, E.K., 1937, Archean rocks in the Piute and Old Woman Mountains, San Bernardino County, California [abs.] in Proceedings of the 35th annual meeting of the Cordilleran Section of the Geological Society of America, held at the California Institute of Technology, Pasadena, California, April 17 and 18, 1936: Geological Society of America Proceedings for 1936, p. 308-309.

Horringa, E.D., 1986, Mesozoic tectonism in the northern Kilbeck Hills, southeastern California [abs.]: Geological Society of America Abstracts with Programs, v. 18, p. 118.

Howard, K.A. and John, B.E., 1984, Geologic map of the Sheep Hole-Cadiz Wilderness Study Area (CDCA-305), San Bernardino County, California: U. S. Geological Survey Miscellaneous Field Studies Map MF-1615-A, scale 1:62,500.

Howard, K.A., John, B.E., and Miller, C.F., 1987, Metamorphic core complexes, Mesozoic ductile thrusts, and Cenozoic detachments: Old Woman Mountains - Chemehuevi Mountains transect, California and Arizona, in Davis, G.H. and VandenVolder, E.M., eds., Geologic diversity of Arizona and its margins: Arizona Bureau of Geology and Mineral Technology Special Paper 5, p. 365-382.

Howard, K.A., Miller, D.M., and John, B.E., 1982, Regional character of mylonitic gneiss in the Cadiz Valley area, southeastern California, in Frost, E.G., and Martin, D.M., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River area, California, Arizona, and Nevada (Anderson-Hamilton volume): San Diego, Calif., Cordilleran Publishers, p. 441-447.

Howard, K.A., Stone, Paul, and Miller, C.F., 1989, Geologic map of the Milligan 15-minute quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2072, scale 1:62,500.

Hutton, D.H.W., 1979, Tectonic slides: A review and reappraisal: Earth Science Reviews, v. 15, p. 151-172.

John, B.E., 1981, Reconnaissance study of Mesozoic plutonic rocks in the Mojave Desert region, in Howard, K.A., Carr, M.D., and Miller, D.M., eds., Tectonic Framework of the Mojave and Sonoran Deserts, California and Arizona: U.S. Geological Survey, Open-File Report 81-503, p. 48-50.

Jones, J.A., 1973, Geology of the northern Kilbeck Hills and an adjacent portion of the Old Woman Mountains, eastern Mojave Desert, San Bernardino County, California: Los Angeles, Calif., University of Southern California, M.S. thesis.

Knoll, M.A., 1985, The early Miocene geologic history of the Old Woman Mountains area, eastern Mojave Desert, California: Nashville, Tenn., Vanderbilt University, M.S. thesis, 186 p.

Knoll, M.A., Miller, C.F., and James, W.C., 1986, Mid-Tertiary stratigraphic and structural evolution of the Piute Mountains and adjacent areas of the Old Woman Mountains region, southeastern California, in volume Trips 5 and 6--Cenozoic stratigraphy, structure, and mineralization in the Mojave Desert: Geological Society of America Annual Meeting, Cordilleran Section, 82nd, Los Angeles, Calif., March 25-28, 1986, Guidebook and volume, p. 43-49.

Kupfer, D.H., and Bassett, A.M., 1962, Geologic reconnaissance map of part of the southeastern Mojave Desert, California: U.S. Geological Survey Mineral Investigation Field Studies Map MF-205, scale 1:125,000.

Miller, C.F., Howard, K.A., and Hoisch, T.D., 1982, Mesozoic thrusting, metamorphism, and plutonism, Old Woman-Piute Range, southeastern California, in Frost, E.G. and Martin, D.L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada (Anderson-Hamilton volume): San Diego, Calif., Cordilleran Publishers, p. 561-581.

Miller, C.F., Wooden, J.L., Bennett, V., Wright, J.E., Solomon, G.C., and Hurst, R.W., in press, Petrogenesis of the composite peraluminous/metaluminous Old Woman-Piute Range batholith, southeastern California: Isotopic constraints, in Anderson, J.L., ed., Cordilleran magmatism: Geological Society of America memoir.

Miller, D.M. and Howard, K.A., 1985, Bedrock geologic map of the Iron Mountains quadrangle, San Bernardino and Riverside Counties, California: U. S. Geological Survey Miscellaneous Field Studies Map MF-1736, scale 1:62,500.

Miller, D.M., Howard, K.A., and Anderson, J.L., 1981, Mylonitic gneiss related to emplacement of a Cretaceous batholith, Iron Mountains, southern California, in Howard, K.A., Carr, M.D., and Miller, D.M., eds., Tectonic framework of the Mojave and Sonoran Deserts: U.S. Geological Survey Open-File Report 81-503, p. 73-75.

Miller, D.M., Howard, K.A., and John, B.E., 1982, Preliminary geology of the Bristol Lake region, Mojave Desert, California, in Cooper, J.T., compiler, Geologic excursions in the California Desert: Geological Society of America Annual Meeting, Cordilleran Section, 78th, Anaheim, Calif., April 19-21, 1982, p. 91-100.

Miller, W.J., 1944, Geology of the Palm Springs-Blythe strip, Riverside County, California: California Journal of Mines and Geology, v. 40, p. 11-72.

Moyle, W.R., Jr., 1967, Water wells and springs in Bristol, Broadwell, Cadiz, Danby, and Lavic Valleys and vicinity, San Bernardino and Riverside Counties, California: California Department of Water Resources, Bulletin 91-14, 17 p.

Reynolds, S.J., Spencer, J.E., and DeWitt, Ed., 1988, Stratigraphy and U-Th-Pb geochronology of Triassic and Jurassic rocks in west-central Arizona: Arizona Geological Society Digest, v. 18, p. 65-80.

Simpson, R.W., Bracken, R.E., and Stierman, D.J., 1984, Aeromagnetic, Bouguer gravity, and interpretation maps of the Sheep Hole-Cadiz Wilderness Study Area (CDCA-305), San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1615-B, 4 sheets, scale 1:62,500.

Spurk, W.H., 1959a, Geology and mineral resources of Township 4 North, Ranges 15 and 16 East, San Bernardino Meridian, San Bernardino County, California: San Francisco, Calif., Southern Pacific Land Company, unpublished map and report, scale 1:24,000.

----- 1959b, Geology and mineral resources of Township 2 North, Ranges 15 and 16 East, San Bernardino Meridian, San Bernardino County, California: San Francisco, Calif., Southern Pacific Land Company, unpublished map and report, scale 1:24,000.

Stone, Paul, Howard, K.A., and Hamilton, Warren, 1983, Correlation of metamorphosed Paleozoic strata of the southeastern Mojave Desert region, California and Arizona: Geological Society of America Bulletin, v. 94, p. 1135-1147.

Stone, Paul, Page, V.M., Hamilton, Warren, and Howard, K.A., 1987, Cretaceous age of the upper part of the McCoy Mountains formation, southeastern California and southwestern Arizona, and its tectonic significance: Reconciliation of paleobotanical and paleomagnetic evidence: Geology, v. 15, p. 561-564.

Streckeisen, A.L., 1973, Plutonic rocks classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks: Geotimes, v. 18, n. 10, p. 26-30.

U.S. Geological Survey, 1981, Aeromagnetic map of the Needles 1° x 2° quadrangle, California and Arizona: U.S. Geological Survey Open-File Report 81-85, scale 1:250,000.

Walker, J.D., 1987, Permian to Middle Triassic rocks of the Mojave Desert, in Dickinson, W.R., and Klute, M.A., Mesozoic rocks of southern Arizona and adjacent areas: Arizona Geological Society Digest, v. 18, p. 1-14.

Wright, J.E., Howard, K.A., and Anderson, J.L., 1987, Isotopic systematics of zircons from Late Cretaceous intrusive rocks, southeastern California: Implications for a vertically stratified crustal column [abs.]: Geological Society of America Abstracts with Programs, v. 19, p. 898.

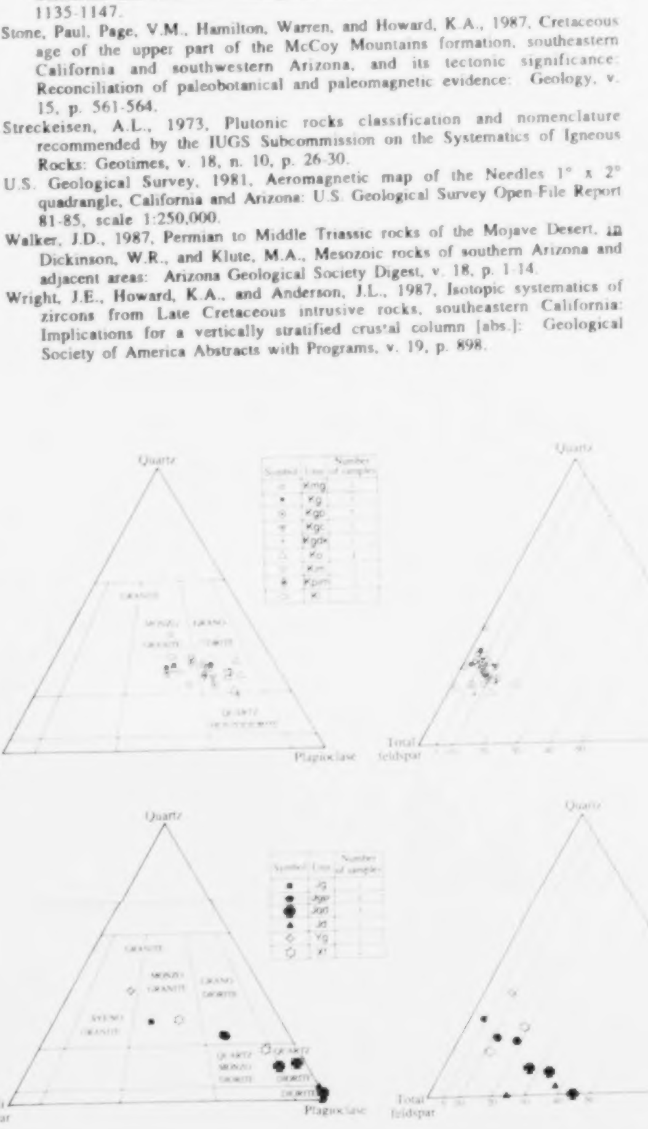


Figure 2. Modal mineralogy for plutonic rocks (based on modal counts averaging 1000 points on stained slabs). Rock names are from Streckeisen (1973). The upper two diagrams are for Cretaceous rocks; the lower two are for Proterozoic and Jurassic rocks.

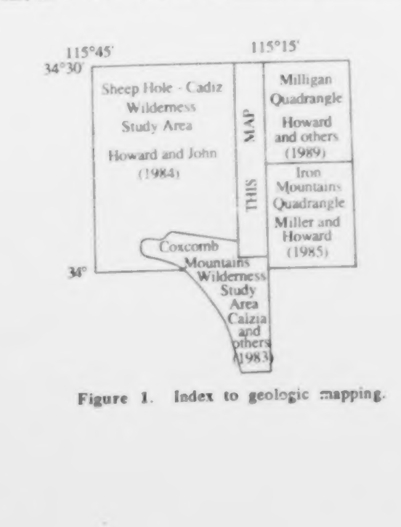


Figure 1. Index to geologic mapping.

GEOLOGIC MAP OF THE EASTERN PARTS OF THE CADIZ LAKE AND CADIZ VALLEY 15-MINUTE QUADRANGLES, SAN BERNARDINO AND RIVERSIDE COUNTIES, CALIFORNIA

By

Keith A. Howard, Eric D. Horringa, David M. Miller, and Paul Stone

1989

Interior—Geological Survey, Reston, Va.—1989
For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225

DEPARTMENT OF THE INTERIOR
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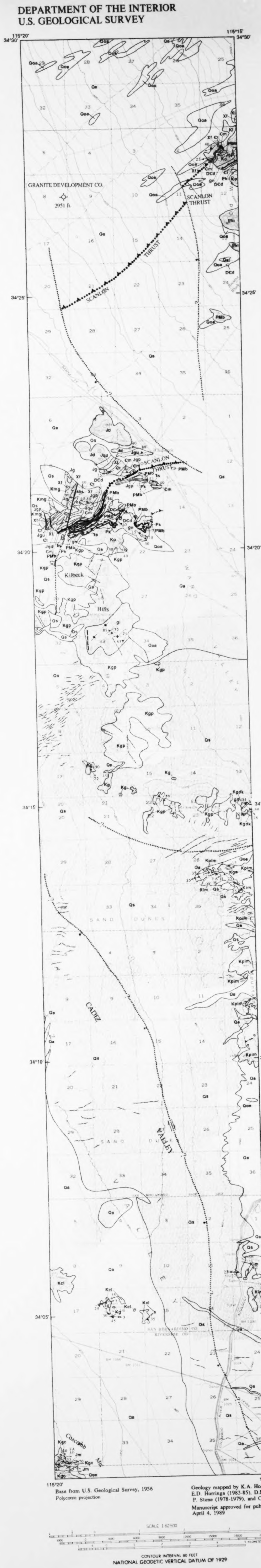
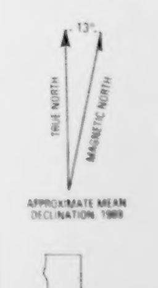
MISCELLANEOUS FIELD STUDIES
MAP MF-2086



Base from U.S. Geological Survey, 1956
Polyconic projection

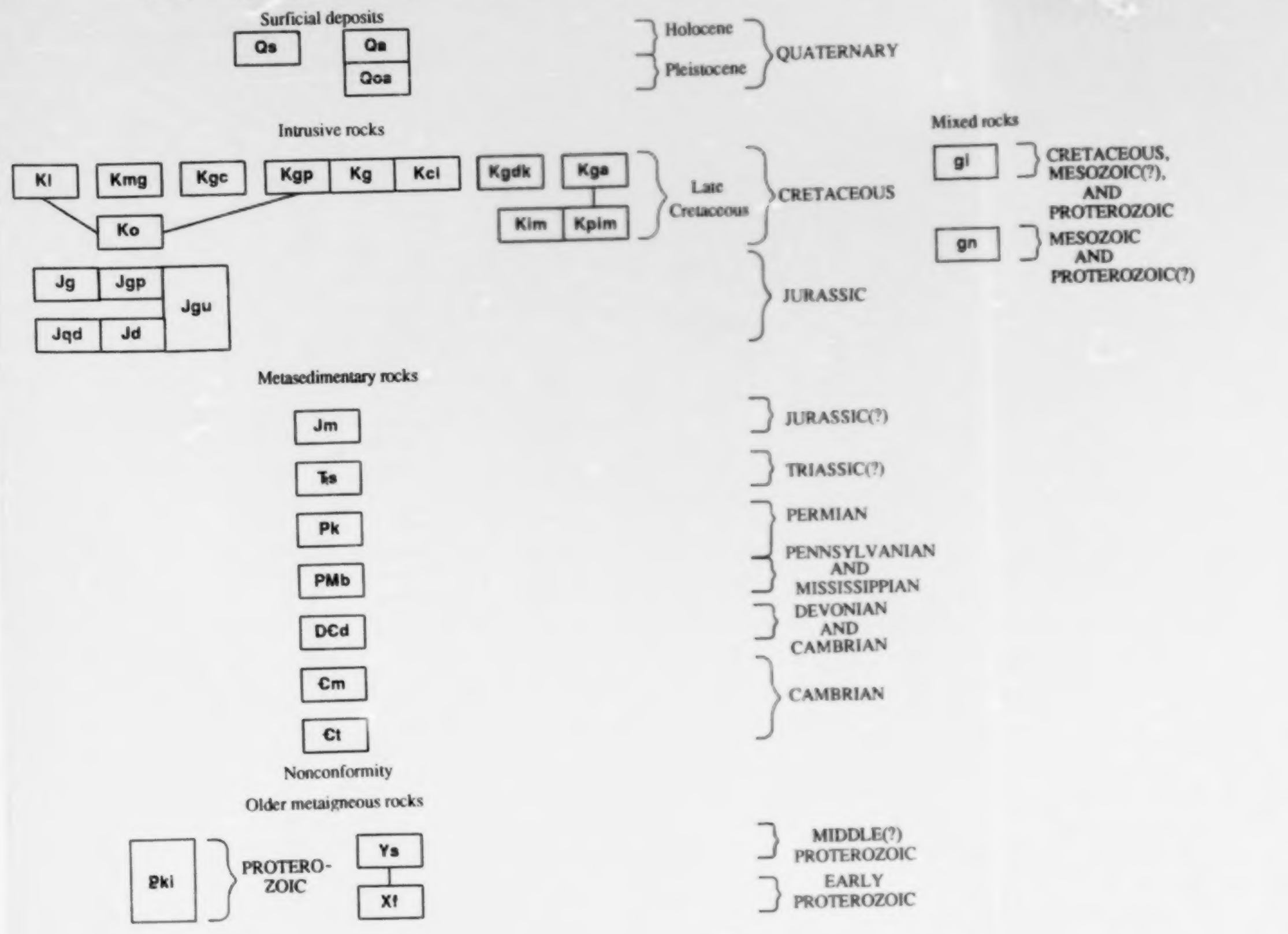
Geology mapped by K.A. Howard (1978-83), E.D. Horringa (1983-85), D.M. Miller (1979), P. Stone (1978-1979), and C.A. Allen (1982).
Manuscript approved for publication, April 4, 1989



LOCATION OF MAP

CORRELATION OF MAP UNITS

[Boxes are adjacent where units are gradational. A connecting line indicates observed intrusion of older rocks by younger rocks]



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qs **Windblown sand (Holocene)**--Well sorted sand. Includes sand sheets and low active and fossil dunes. Commonly banked against the northwest sides of hills. Contains pebble lag deposits in places

Qa **Alluvial fan deposits (Holocene)**--Poorly sorted sandy gravel, composed of locally derived subangular to angular clasts. May possibly be, in part, Pleistocene in age

Qoa **Older alluvium (Pleistocene)**--Poorly sorted sandy gravel, forming low dissected benches. Composed of locally derived subangular to angular clasts. Soil development is greater than for unit Qa. May possibly be, in part, Holocene in age

INTRUSIVE ROCKS

Kl **Leucogranite (Late Cretaceous)**--In the Old Woman Mountains. Lithologically equivalent rocks in the adjacent Milligan quadrangle are included with the leucogranite of Milligan by Howard and others (1989). White, medium-grained magnetite-biotite monzogranite, sparsely porphyritic. Mafic mineral content 4 modal percent. Contains allanite and sphene. SiO_2 content 75 percent (one sample). Has metamorphic texture and is lineated. Invades the projected position of the Scanlon thrust and may postdate it. Probably cuts the Old Woman Mountains Granodiorite. Small unmapped dikes cut the Fenner Gneiss in the northern Kilbeck Hills

Kmg **Two-mica granite (Late Cretaceous)**--In the northern Kilbeck Hills. Yellowish-gray-weathering, fine- to medium-grained, equigranular to seriate garnet-biotite-muscovite leucomonzogranite. Mafic mineral content 0.1 to 3 modal percent. Rock contains iron-titanium oxide, myrmekite, late crystallizing muscovite and microcline; one sample contains partly resorbed garnet and no biotite. SiO_2 content of two samples is 75 and 76 percent. Pegmatite is present at margins of intrusion and in dikes. Rarely foliated. Equivalent in lithology and structural position to two-mica granite of the Sweetwater Wash pluton 10 km northeast of the map area in the Old Woman Mountains; that pluton is dated at 70-75 Ma by U-Pb method on zircon and K-Ar method on biotite, and it is cross-cut by the 70-75-Ma Old Woman Mountains Granodiorite (Miller and others, in press)

Kgc **Porphyritic granodiorite in Coxcomb Mountains (Late Cretaceous)**--In southwest corner of map area. Mapped and described by Calzia and others (1983) as part of the Coxcomb Granodiorite of Miller (1944). Light-gray-weathering, medium-grained biotite granodiorite and monzogranite, generally containing 1-cm-long alkali feldspar phenocrysts. Mafic mineral content 4-10 modal percent. Contains oscillitory-zoned plagioclase, euhedral sphene, apatite, zircon, allanite. Closely resembles the porphyritic granodiorite in the Kilbeck Hills (Kgp), and probably represents a closely related pluton

Kgp **Porphyritic granodiorite in Kilbeck Hills (Late Cretaceous)**--Light-gray-weathering, medium-grained porphyritic biotite granodiorite. Alkali-feldspar phenocrysts 1 cm across generally abundant. Mafic mineral content is 5 to 13 modal percent. Biotite 0.5-1 mm. Euhedral sphene, iron-titanium oxide, apatite, zircon, and trace of allanite are present. Plagioclase is oscillatory zoned. Hypidiomorphic granular. SiO_2 content of three samples is 69 to 74 percent. Predominantly massive. Rocks at lat 34°15' are foliated, recrystallized, and contain 1.5-cm-long alkali-feldspar phenocrysts

Kg **Granite and granodiorite (Late Cretaceous)**--In the southern Kilbeck Hills, Cadiz Valley, and aplitic dikes (unmapped) in the Coxcomb Mountains. Very light gray weathering, medium-grained, equigranular biotite monzogranite and granodiorite. Mafic mineral content 2 to 13 modal percent. Biotite (subhedral and euhedral) 0.5-1 mm. Sphene, iron-titanium oxide, sparse muscovite, apatite, zircon, and trace euhedral allanite are present. Mylonitic foliation and lineation are present at lat 34°05' in southern Cadiz Valley

Kcl **Granodiorite of Cadiz Lake (Late Cretaceous)**--In southern Cadiz Valley. Light-gray-weathering, medium- to coarse-grained, porphyritic biotite granodiorite and monzogranite. Alkali feldspar phenocrysts, 2-3 cm across, contain zonal inclusions of plagioclase, sphene, and biotite. Phenocrysts are coarser than in other Cretaceous units. Mafic mineral content is 5-6 modal percent. Iron-titanium oxide, apatite, allanite, and as much as 1 percent sphene present. Contains secondary muscovite, chlorite, and (where mylonitic) epidote. Foliated, locally lineated; mylonite layers are present. The porphyritic texture and mylonitic structure are illustrated and discussed in Howard and others (1982, photograph fig. 3). Gradational to gneissic nonporphyritic granite of unit Kg

Kgdk **Porphyritic granodiorite of southeastern Kilbeck Hills (Late Cretaceous)**--Medium-light-gray-weathering, gneissic, medium-grained biotite granodiorite to quartz monzodiorite. Contains alkali-feldspar phenocrysts 1 to 2 cm long. Mafic mineral content about 9 modal percent. Darker and contains less quartz than nearby rocks of unit Kgp but is probably closely related. Contains iron-titanium oxide, apatite, zircon, euhedral allanite-epidote, and secondary muscovite and chlorite. SiO_2 content 68 percent (one sample)

Kga **Garnet aplite gneiss (Late Cretaceous)**--In the northern Iron Mountains. Leucocratic fine- to medium-grained garnet-muscovite-biotite syenogranite gneiss. Forms a deformed dike that cuts the porphyritic granodiorite gneiss of Iron Mountains (Kpim). Mylonitic foliation is perpendicular to the dike

Ko **Old Woman Mountains Granodiorite (Late Cretaceous)**--In the Old Woman Mountains and northern Kilbeck Hills. Medium-light-gray-weathering sphene-hornblende-biotite granodiorite. Medium grained, equigranular, hypidiomorphic granular. Contains igneous foliation in the Kilbeck Hills and metamorphic foliation in the Old Woman Mountains. Rare alkali-feldspar phenocrysts. Euhedral sphene is conspicuous in hand specimen. Mafic mineral content 14 to 19 modal percent. Plagioclase shows oscillatory zoning. Iron-titanium oxide and trace amounts of apatite, zircon, and allanite are present. Euhedral epidote of probable magmatic origin is present in the Old Woman Mountains. SiO_2 content 64-65 percent for two samples from the Kilbeck Hills. Dated by U-Pb method on zircon as about 71 Ma in the Old Woman Mountains 11 km east of the map area (Miller and others, in press). Intrudes the dark gneiss unit (gn). Cut by and possibly gradational with the porphyritic granodiorite in the Kilbeck Hills (Kgp). Forms the Old Woman pluton, exposed mainly in the adjacent Milligan quadrangle east of the map area (Miller, Howard, and Hoisch, 1982; Howard and others, 1989)

Kim **Granite gneiss of Iron Mountains (Late Cretaceous)**--Leucocratic muscovite-biotite monzogranite mylonitic gneiss. Commonly cut by aplite and pegmatite dikes. Subequigranular, fine to medium grained. Mafic mineral content 3 to 9 modal percent. Contains iron-titanium oxide, apatite, zircon; locally contains garnet. SiO_2 content 72 and 73 percent in two samples. Rocks in northern exposure (lat 34°13') are the more mafic and are gradational to porphyritic unit Kpim. Some rocks of unit Kim intrude unit Kpim in the adjacent Iron Mountains quadrangle. Dating of biotite (from exposure at lat 39°06') by the K-Ar technique gave 65 Ma, and dating of biotite and whole rock by the Rb-Sr technique gave 61 Ma (W.A. Rehrig, in Miller and others, 1981). Lineated surfaces called "hot slickensides" are steeper than foliation; the lineations strike parallel to mylonitic lineation

Kpim **Porphyritic granodiorite gneiss of Iron Mountains (Late Cretaceous)**--Brownish-gray-weathering muscovite-biotite granodiorite and monzogranite gneiss. Commonly cut by aplite and pegmatite dikes. Contains zoned 1-cm-long alkali-feldspar augen porphyroclasts in a fine- to medium-grained mylonitic matrix. Mafic mineral content is 5 to 8 modal percent. Contains iron-titanium oxide, epidote, zircon, and apatite. SiO_2 content 74 percent (one sample). East of the map area, the U-Pb age on zircon is 70-73 Ma (Wright and others, 1987)

Jg **Granite gneiss (Jurassic)**--In the northern Kilbeck Hills. Light-gray-weathering, fine-grained, seriate biotite monzogranite and monzogranite gneiss. Mafic mineral content is 4 to 8 modal percent. Contains iron-titanium oxide and small amounts of muscovite, zircon (with pleochroic halos in biotite), allanite, and apatite. SiO_2 content 73 percent (one sample). Cuts the quartz diorite gneiss (Jqd) and the Fenner Gneiss (Xf), and is cut by the two-mica granite (Kmg). Deformed into gneiss where near Paleozoic strata and deformed into dark fissile gneiss where diked into Paleozoic strata

Jgp **Porphyritic granite gneiss (Jurassic)**--In the northern Kilbeck Hills and the Old Woman Mountains. Brownish-gray-weathering biotite monzogranite and granodiorite gneiss. Roundish to rectangular, very light gray to pale-pink, 1-cm-long augen phenocrysts and porphyroclasts of alkali feldspar and plagioclase, commonly recrystallized to quartz + feldspar, are in a dark, medium-grained to very fine grained, foliated matrix, commonly showing metamorphic textures indicative of annealing. Contains mafic microgranitoid enclaves about 2 cm across. Mafic mineral content is 8 to 15 modal percent. Contains iron-titanium oxide, sphene, rare euhedral epidote, local hornblende, and local metamorphic muscovite. SiO_2 content 66 and 72 percent on two samples. Gradational into the granite gneiss (Jg). Cuts the quartz diorite gneiss (Jqd), the Fenner Gneiss (Xf), and Paleozoic strata, and is cut by the two-mica granite (Kmg) and the Old Woman Mountains Granodiorite (Ko)

Jqd **Quartz diorite gneiss (Jurassic)**--In the northern Kilbeck Hills. Dark-weathering, medium-grained hornblende-biotite gneiss of quartz diorite, granodiorite, diorite, and quartz monzodiorite composition. Mafic mineral content is 20 to 40 modal percent. Xenoblastic texture shows evidence of annealing. Contains 1 percent or more each sphene and iron-titanium oxide. SiO_2 content 54 and 55 percent (two samples). Cuts the Fenner Gneiss and Paleozoic units, and is cut by units Jg and Jgp. U-Pb concordant age on zircon is about 162 Ma (J.E. Wright, written commun., 1986)

Jd **Diorite (Jurassic)**-- In the northern Kilbeck Hills. Dark-gray, medium-grained hornblende and hornblende-clinopyroxene diorite and gabbro. Commonly recrystallized but shows gabbroic igneous protolith texture. Mafic mineral content 20 to 50 modal percent. Contains sphene, iron-titanium oxide, epidote, late-crystallizing igneous apatite. SiO_2 content 51 percent (one sample). Contains calc-silicate inclusions probably derived from Paleozoic strata

Jgu **Gneissic granitoid rocks, undivided (Jurassic)**--Units Jg, Jgp, Jqd, and Jd, where they are not mapped separately

METASEDIMENTARY ROCKS

Jm **Metasedimentary rocks (Jurassic?)**--In the Coxcomb Mountains. Phyllite, hornfels, calc-silicate granofels, quartzitic phyllite, and fine-grained amphibolite. Calzia and others (1983) considered the unit as part of the McCoy Mountains Formation of Miller (1944). Mineral assemblages include garnet-muscovite-biotite (Calzia and others, 1983), plagioclase-tremolite-diopside, and epidote-hedenbergite-quartz-plagioclase. Intruded by unit Kgc and by an unmapped, older metamorphosed biotite-hornblende quartz diorite to quartz monzodiorite gneiss (mafic content 20 to 30 percent) that may be equivalent to a Jurassic granitoid recognized a few kilometers west of the map area (Calzia and others, 1983)

TRs **Schist and gneiss (Triassic?)**--Dark-gray fissile gneiss and schist. Overlies the metamorphosed Kaibab Limestone. Lower part consists of epidote-bearing feldspathic mica schist and gneiss. Upper part consists of feldspathic garnet-two-mica schist and gneiss and includes sillimanite-mica schist. May correlate with clastic rocks of the Buckskin Formation of Reynolds and others (1988) in western Arizona and with Triassic strata elsewhere in southeastern California described by Stone and others (1983) and Walker (1987)

Pk **Metamorphosed Kaibab, Coconino, and Hermit Formations, undivided (Permian)**--The metamorphosed Kaibab Limestone consists of gray and white dolomitic calcitic marble. The underlying metamorphosed Coconino Sandstone consists of fine-grained metaquartzite. The underlying metamorphosed Hermit Shale consists of calc-schist; it overlies the metamorphosed Bird Spring Formation

PMb **Metamorphosed Bird Spring Formation (Permian and Pennsylvanian) and Redwall Limestone (Mississippian)**--The metamorphosed Bird Spring Formation consists of layered marble, dusky-brown-weathering quartzitic marble, and thin vitreous metaquartzite. Contains diopside. In lower thrust sheets of the Kilbeck Hills, the metamorphosed Bird Spring is partly dusky-brown-weathering wollastonite marble and wollastonite rock. The underlying metamorphosed Redwall Limestone consists of medium- to coarse-grained, white calcitic marble containing dusky-brown siliceous metachert lensoid layers a few centimeters thick. The metamorphosed Redwall overlies the dolomite marble unit

DꞒd **Dolomite marble (Devonian and Cambrian)**--Greenish-yellow, massive to bedded dolomite marble. Inferred to correlate with the Sultan and Nopah Formations and upper part of the Bonanza King Formation. Overlies the banded marble unit

Ꞓm **Banded marble (Cambrian)**--Gray and white, laminated to mottled calcitic marble. Correlated with the Muav Limestone and the lower part of the Bonanza King Formation. Overlies the Bright Angel Shale

Ꞓt **Metamorphosed Tapeats Sandstone and Bright Angel Shale, undivided (Cambrian)**--The metamorphosed Bright Angel consists of muscovite-biotite and sillimanite-muscovite-biotite schist in both the Kilbeck Hills and the Old Woman Mountains. The underlying metamorphosed Tapeats consists of an upper part of white to yellowish-gray metaquartzite, considered equivalent to the Zabriskie Quartzite, and a lower part of brown, crossbedded, arkosic, partly conglomeratic metaquartzite, considered equivalent to the Wood Canyon Formation. The Tapeats rests nonconformably on the Fenner Gneiss (Xf) and probably on the Kilbeck Gneiss (Ᵽki)

OLDER METAIGNEOUS ROCKS

Ᵽki **Kilbeck Gneiss (Proterozoic protolith age)**--In the Old Woman Mountains. Medium-grained biotite monzogranite gneiss characterized by wispy foliation consisting of dark mafic stripes and light-colored quartzofeldspathic stripes. Mafic mineral content about 10 modal percent

Ys **Syenogranite (Middle? Proterozoic)**--Mapped only at one locality in the northern Kilbeck Hills (SW1/4NW1/4 sec. 16, T. 3 N., R. 16 E.). Well-foliated, coarse-grained, quartz-rich leucocratic syenogranite characterized by tabular to lensoid 1- to 2-cm-long megacrysts of microcline. Contains biotite and some muscovite, iron-titanium oxide, and zircon (with pleochroic halos in biotite). Intrudes the Fenner Gneiss

Xf **Fenner Gneiss (Early Protrerozoic)**--In the northern Kilbeck Hills and Old Woman Mountains. Unit originally introduced by Hazzard and Dosch (1937) (also called the Fenner Granite Gneiss). Dark biotite-rich augen gneiss of monzogranite, granodiorite, and quartz monzodiorite composition. Characterized by very coarse grained, white, blocky alkali feldspar megacrysts 1 to 6 cm across in a biotite-rich matrix. Mafic mineral content is 11 to 20 modal percent. Contains iron-titanium oxide, apatite, zircon, and locally muscovite. Megacrysts are generally recrystallized to quartz + feldspar and are in places deformed to rod shapes. SiO_2 content 64 percent (one sample of quartz monzodiorite). Includes layers and bodies of biotite-hornblende quartz diorite gneiss. Dated by U-Pb method on zircon at about 1.67-1.70 Ga in the Kilbeck Hills (L.T. Silver, oral commun., 1982)

MIXED ROCKS

gi **Granite intrusive into gneiss (Cretaceous, Mesozoic?, and Proterozoic)**--In the central Kilbeck Hills. Predominantly granite and gneiss. Composed of augen gneiss (Ᵽki or Xf), dark gneiss (gn?), and amphibolite, all intimately intruded by granite and granodiorite associated with units Kpg and Kg

gn **Dark gneiss (Mesozoic and Proterozoic?)**--In the Kilbeck Hills and Old Woman Mountains. Highly foliated, medium-dark-gray to medium-gray gneiss, intruded by units Ko and Kgdk. Largely quartzofeldspathic biotite gneiss. In the northern Kilbeck Hills includes, among other rock types, rocks lithologically identical to the Jurassic porphyritic granite gneiss (Jgp) and biotite-muscovite-quartz schist. The latter rock type is probably a paraschist; two analyzed samples consisted of the following (in percent; analyzed by J. Ardith, F. Bartel, J. Stewart, J. Taggart, and L. Espos, U.S. Geological Survey): Sample H83Ki-29--SiO_2 (72.8), Al_2O_3 (13.3), FeO (1.33), Fe_2O_3 (0.47), MgO (0.74), CaO (0.73), Na_2O (2.38), K_2O (6.33), TiO_2 (0.67), P_2O_5 (0.09), MnO (0.02), H_2O+ (0.41), H_2O- (0.05), CO_2 (0.13); sample H83Ki-30--SiO_2 (78.9), Al_2O_3 (10.0), FeO (1.36), Fe_2O_3 (1.60), MgO (0.88), CaO (0.45), Na_2O (1.79), K_2O (2.25), TiO_2 (0.67), P_2O_5 (0.09), MnO (0.02), H_2O+ (1.14), H_2O- (0.09), CO_2 (0.12). The unit is interpreted as a tectonic schist (Hutton, 1979) of heterogeneous protolith

Contact

Fracture lineament

Tectonic slide (ductile thrust or lag fault)--Teeth on upper plate. Dotted where concealed. Heavy line indicates the slide interpreted as the Scanlon thrust

Normal or oblique slip fault--Showing dip. Dashed where inferred; dotted where concealed; queried where inferred from aeromagnetic and gravity data. Bar and ball on downthrown side. Arrows show strike or oblique slip

Foliation--Showing strike and dip

Metamorphic-Inclined

Metamorphic-Vertical

Igneous-Inclined

Igneous-Vertical

Lineation--Showing trend and plunge. May be combined with foliation symbols

Mylonitic

Nonmylonitic or annealed

Fold axis

Mineralized joints--Showing strike and dip. Surfaces exhibit white mica and hematite

Crest of sand dunes--Mapped from aerial photographs taken in 1973 and 1975

Test hole drilled for oil or gas--Abandoned. Depth in feet indicated

ABANDONED TEST HOLE DRILLED FOR OIL OR GAS

Mojave No. 1, sec. 8, T. 4 N., R. 16 E. Drilled and abandoned by Granite Development Company in 1979. Summary driller's log reported that the sediments from top to total depth (2951 ft) are granite-wash alluvium varying from course to very coarse grained; finer grained with depth. A few beds of fine-grained subrounded sand were encountered. At 1450 ft the beds became clayey, but clay then decreased downward. Only fresh water was encountered in the hole.

INTRODUCTION

This map covers a strip in the Mojave Desert that fills a gap between other published geologic maps (fig. 1). The map area includes parts of Cadiz and Ward Valleys, the Kilbeck Hills (north-central part of the map), and parts of the Iron Mountains (southeast part of the map), Old Woman Mountains (northeast part of map), and Coxcomb Mountains (southwest corner of the map). Previous geologic maps covering parts of the area can be found in Danehy and Collier (1959), Spurk (1959a, b), Kupfer and Bassett (1962), Bishop (1963), Moyle (1967), Evenson (1973), Jones (1973), Davis and Kuniyoshi (1974), Calzia and others (1983), Stone and others (1983), and Brown (1984). An earlier version of the present map was included as a base for gravity and aeromagnetic maps of the region (Simpson and others, 1984). The present map is modified to incorporate the results of 1:6,000-scale geologic mapping by Horringa (1986) of the northern Kilbeck Hills.

GEOLOGIC SUMMARY

PRE-QUATERNARY ROCKS

Two Proterozoic orthogneiss units crop out that are more widely exposed east and northeast of the map area--the Fenner Gneiss and the Kilbeck Gneiss (Hazzard and Dosch, 1937; Miller, Howard, and Hoisch, 1982; Bender and Miller, 1987; Howard and others, 1989). Figure 2 indicates modal compositions of the Fenner and many other plutonic units. A small exposure of gneissic syenogranite (Ys) that intrudes the Early Proterozoic Fenner resembles Middle Proterozoic rocks described elsewhere in southeastern California by Anderson (in press). The Proterozoic rocks together represent a basement overlain nonconformably by a sequence of Paleozoic and Triassic(?) strata.

These strata are correlated on the basis of lithologic sequence to a regional sequence of shallow-water marine formations (Stone and others, 1983). The stratified Paleozoic and Triassic(?) units are metamorphosed, tectonized, and attenuated and in places are too thin to show on the map. Contacts between them are nearly all parallel to layering, and conformable contacts can be distinguished from tectonic ones only on the basis of whether the sequence is stratigraphically correct or disrupted.

Metasedimentary rocks (Jm) studied by Calzia and others (1983) at the southwest corner of the map area are tentatively correlated to part of the McCoy Mountains Formation of Harding and Coney (1985) and are assigned a Jurassic(?) age; J.P. Calzia (unpub. data, 1983; Calzia and others, 1983) has established that in this map area those rocks are intruded by now-metamorphosed plutonic rocks that resemble Jurassic protoliths west of the map area. Elsewhere, part of the McCoy Mountains Formation is Cretaceous in age (Stone and others, 1987). A diverse suite of Jurassic metaplutonic rocks, for which counterpart rocks are present in ranges to the west of the area (Miller, Howard, and John, 1982; Howard and John, 1984), crops out in the Kilbeck Hills.

Late Cretaceous granite and granodiorite compose most of the pre-Quaternary rocks in the map area. The two-mica granite (Kmg) and the Old Woman Mountains Granodiorite (Ko) are more widely exposed east of the map area in the Old Woman Mountains, where they have been grouped as the Old Woman-Piute composite batholith and characterized isotopically and chemically by Miller, Howard, and Hoisch (1982) and Miller and others (in press). The leucogranite (Kl) probably correlates with the leucogranite of Milligan mapped in the Milligan quadrangle (Howard and others, 1989). The other mapped Late Cretaceous plutonic rocks, which form several plutons, have been included both as part of the Coxcomb Granodiorite of Miller (1944; Calzia, 1982; Calzia and others, 1983) and (or) as part of the Cadiz Valley batholith (John, 1981; Miller, Howard, and John, 1982; Howard and John, 1984). The rocks in the Iron Mountains are highly deformed (Miller and Howard, 1985). Outside the map area, U-Pb dating on zircon of some of the Late Cretaceous units (Kpim, Kmg, Ko) and closely related units establishes that they are all about 70-73 Ma (Wright and others, 1987; Calzia and others, 1986). Unit Kgp of the Cadiz Valley batholith intrudes the Old Woman Mountains Granodiorite (Ko) in the Kilbeck Hills.

STRUCTURE

Proterozoic, Paleozoic, Triassic(?), and Jurassic rocks in the northern Kilbeck Hills and Old Woman Mountains are metamorphosed, foliated, and deformed in a northeast-trending zone of ductile thrust faulting and folding. Amphibolite metamorphic grade for the pre-Late Cretaceous rocks is indicated by sillimanite in the metamorphosed Bright Angel Shale in the Kilbeck Hills and Old Woman Mountains and diopside in Paleozoic calc-silicate rocks in the Kilbeck Hills; diopside is present also in the Jurassic(?) metasedimentary rocks in the Coxcomb Mountains. The thrust zone extends northeast of the map area through and beyond the Old Woman Mountains (Miller, Howard, and Hoisch, 1982; Howard and others, 1987, 1989). A distinctive structural sequence in the Kilbeck Hills typifies much of the 45-km length of this structural zone and its environs. The structural sequence dips northwest and consists, in ascending order, of (1) the Late Cretaceous Old Woman Mountains Granodiorite, (2) the dark gneiss, (3) mostly upright upper (and some lower) Paleozoic and Triassic strata, (4) a thrust fault, (5) inverted lower Paleozoic strata and their inverted Proterozoic basement rocks, and (6) Late Cretaceous two-mica granite that intrudes the Proterozoic rocks. This sequence contains several tectonic slides--a term applied to ductile, concordant synmetamorphic or premetamorphic faults in a zone of penetrative deformation (Bailey, 1910; Hutton, 1979). The Late Cretaceous two-mica granite and the Old Woman Mountains Granodiorite, although they follow consistent positions in the structural sequence, cut the slides and the ductilely deformed rocks. The granodiorite is itself locally deformed.

In the Old Woman Mountains northeast of the map area, the name Scanlon thrust is applied to the prominent tectonic slide (4) that juxtaposes the inverted Proterozoic and lower Paleozoic hanging-wall rocks above the upright upper Paleozoic strata and Triassic footwall rocks (Howard and others, 1987). The comparable structure in the Kilbeck Hills is here also proposed as the Scanlon thrust. It is one of the highest of the tectonic slides. In the Kilbeck Hills some of the other nearby slides have nearly coequal stratigraphic throw.

An aeromagnetic low, north of a high, tracks near the Scanlon thrust both in the Kilbeck Hills and northeast of the map area in the Old Woman Mountains (U.S. Geological Survey 1981; Simpson and others, 1984). The aeromagnetic gradient may represent the southern boundary of nonmagnetic Late Cretaceous two-mica granite against the more magnetic Fenner Gneiss, mafic Jurassic rocks, and Late Cretaceous Old Woman Mountains Granodiorite. A corresponding aeromagnetic gradient provides a basis for mapping the inferred concealed Scanlon thrust in lowlands 5 to 8 km north of the Kilbeck Hills. The aeromagnetic low here may in part be due to thick alluvial fill, which is at least 2,951 ft (900 m) thick at the drill hole shown on the map.

The Jurassic plutonic rocks in the Kilbeck Hills are metamorphosed and foliated parallel to the slides. Tectonic plates in the Kilbeck Hills above and below the Scanlon thrust and the plate composed of the dark gneiss unit at the base of the zone of sliding contain some of the deformed, premetamorphic, porphyritic granite gneiss (Jurassic), which suggests that either the slides partly predate the porphyritic granite gneiss, the protolith was regionally widespread, or offsets on the slides in the Kilbeck Hills are small. The dark gneiss unit at the base of the zone of sliding is highly strained, lithologically heterogeneous, and stratigraphically out of place as evidenced by paraschist of unknown (but not Paleozoic) protolith age juxtaposed out of sequence against Paleozoic formations. The dark gneiss unit consistently is in a structural position below Paleozoic strata and above the postsliding Old Woman Mountains Granodiorite over a strike length of 45 km (Howard and others, 1987). These characteristics suggest its origin as an allochthonous tectonic schist (see Hutton, 1979) formed in a zone of high strain.

Mylonitic foliation and lineation overprint some of the Late Cretaceous plutonic rocks, particularly in the Iron Mountains. Miller and others (1981), Howard and others (1982), and Miller and Howard (1985) discussed the character of the mylonitic deformation in the Iron Mountains, reported K-Ar and Rb-Sr isotopic evidence for a latest Cretaceous age, and interpreted the deformation as related to pluton emplacement.

Surficial deposits conceal several postplutonic faults in the map area. Inferred positions of these faults were mapped using a combination of geologic, aeromagnetic, and gravity data. A concealed east-striking fault, coincident with an aeromagnetic low, juxtaposes granodiorite in the Kilbeck Hills against mylonitic granite and granodiorite units in the Iron Mountains. Late Cretaceous metamorphic lineations south of the fault (in the Iron, Granite, Coxcomb, and Sheep Hole Mountains) strike southwest-northeast, whereas those north of the fault in the Kilbeck Hills and in the Old Woman Mountains to the east strike mainly southeast-northwest. This contrast in regional trends of Late Cretaceous metamorphic lineations across the fault suggest that the fault may be regionally important.

Two faults striking approximately north beneath Ward Valley are inferred in order to explain (1) the apparent left-lateral separation, from the Kilbeck Hills to the Old Woman Mountains, of the structural sequence that includes the Scanlon thrust, (2) similar separation of the aeromagnetic gradient associated with this sequence, (3) greater attenuation of units and probably higher metamorphic grade in the Old Woman Mountains than in the Kilbeck Hills, (4) slightly younger Late Cretaceous K-Ar mica cooling ages in the Kilbeck Hills than in the Old Woman Mountains (Miller, Howard, and Hoisch, 1982), and (5) aeromagnetic and gravity gradients (Simpson and others, 1984) that suggest steps in the buried bedrock surface. Reasons (3) and (4) suggest that rocks in the Kilbeck Hills represent a higher structural level that was downdropped from rocks to the east in the Old Woman Mountains. This down-to-west sense of offset for the buried faults agrees with the sense on the mapped faults in the Kilbeck Hills, on faults in the Old Woman Mountains east of the map area (Howard and others, 1989), and on a Miocene normal fault system on strike a few kilometers north of the map area between the Ship and Old Woman Mountains (Knoll, 1985; Knoll and others, 1986).

Cadiz Valley is inferred to be a right-oblique pull-apart graben. A graben structure is inferred from gravity and aeromagnetic data (Simpson and others, 1984) and seismic-reflection profiling (D.A. Okaya and E.G. Frost, unpublished data, 1987). A steep north margin of the Cretaceous Cadiz Valley batholith, represented on this map by the north contact of unit Kgp, shows a possible 8-km right separation across Cadiz Valley to the Calumet Mountains 20 km west of the map area (Howard and John, 1984). A right-slip sense, while not compelling, is consistent with other regional geologic data. Consequently a right-oblique concealed fault is mapped in Cadiz Valley. The inferred fault is positioned where gravity and magnetic gradients are present (Simpson and others, 1984).

REFERENCES CITED

Anderson, J.L., in press, Proterozoic anorogenic granites of the southwestern U.S.: Arizona Geological Society Digest, v. 17.

Bailey, E.B., 1910, Recumbent folds in the schists of the Scottish Highlands: Geological Society London Quarterly Journal, v. 66, p. 586-608.

Bender, E.E. and Miller, C.F., 1987, Petrology of the Fenner Gneiss, a major Proterozoic metaplutonic unit in the eastern Mojave Desert, Calif.: Geological Society of America Abstracts with programs, v. 19, p. 358.

Bishop, C.C., 1963, Geologic Map of the Needles Sheet: California Division of Mines and Geology, Geologic Map of California, Olaf P. Jenkins Edition, scale 1:250,000.

Brown, H.J., 1984, Correlation of metamorphosed Paleozoic strata of the southeastern Mojave Desert region, California and Arizona: Discusssion: Geological Society of America Bulletin, v. 95, p. 1482-1485.

Calzia, J.P., 1982, Geology of granodiorite in the Coxcomb Mountains, southeastern California, in Frost, E.G., and Martin, D.M., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada (Anderson-Hamilton volume): San Diego, Calif., Cordilleran Publishers, p. 173-180.

Calzia, J.P., DeWitt, Ed, and Nakata, J.K., 1986, U-Th-Pb age and initial strontium isotopic ratios of the Coxcomb Granodiorite and a K-Ar age of olivine basalt from the Coxcomb Mountains, southern California: Isochron/West, no. 47, p. 3-8.

Calzia, J.P., Kilburn, J.E., Simpson, R.W., Jr., Allen, C.M., Leszcykowski, A.M., and Causey, J.D., 1983, Mineral resource potential map of the Coxcomb Mountains Wilderness Study Area (CDCA-328), San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1603-A, scale 1:62,500.

Danehy, E.A., and Collier, J.T., 1959, Geology and mineral resources of Township 3 North, Ranges 15 and 16 East, San Bernadino Meridian, San Bernardino County, California: San Francisco, Calif., Southern Pacific Land Coumpany, unpublished map and report, scale 1:24,000.

Davis, G.A., and Kuniyoshi, S., 1974, Geologic map of the Kilbeck Hills-western Old Woman Mountains area, Needles Map Sheet, California, in Woodward-McNeill and Associates, in Southern California Edison Company, Information concerning site characteristics, Vidal Nuclear Generating Station, Vol. V, Appendix 2.5-E, fig. E-9, scale 1:20,560 (approx.).

Evenson, W.A., 1973, Geology of the southern Kilbeck Hills and an adjacent portion of the Old Woman Mountains, eastern Mojave Desert, San Bernardino County, California: Los Angeles, Calif., University of Southern California, M.S. thesis.

Harding, L.E. and Coney, P.H., 1985, The geology of the McCoy Mountains Formation, southeastern California and southwestern Arizona: Geological Society of America Bulletin, v. 96, p. 755-769.

Hazzard, J.C. and Dosch, E.K., 1937, Archean rocks in the Piute and Old Woman Mountains, San Bernardino County, California [abs.] in Proceedings of the 35th annual meeting of the Cordilleran Section of the Geological Society of America, held at the California Institute of Technology, Pasadena, California, April 17 and 18, 1936: Geological Society of America Proceedings for 1936, p. 308-309.

Horringa, E.D., 1986, Mesozoic tectonism in the northern Kilbeck Hills, southeastern California [abs.]: Geological Society of America Abstracts with Programs, v. 18, p. 118.

Howard, K.A. and John, B.E., 1984, Geologic map of the Sheep Hole-Cadiz Wilderness Study Area (CDCA-305), San Bernardino County, California: U. S. Geological Survey Miscellaneous Field Studies Map MF-1615-A, scale 1:62,500.

Howard, K.A., John, B.E., and Miller, C.F., 1987, Metamorphic core complexes, Mesozoic ductile thrusts, and Cenozoic detachments: Old Woman Mountains - Chemehuevi Mountains transect, California and Arizona, in Davis, G.H. and VandenVolder, E.M., eds., Geologic diversity of Arizona and its margins: Arizona Bureau of Geology and Mineral Technology Special Paper 5, p. 365-382.

Howard, K.A., Miller, D.M., and John, B.E., 1982, Regional character of mylonitic gneiss in the Cadiz Valley area, southeastern California, in Frost, E.G., and Martin, D.M., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River area, California, Arizona, and Nevada (Anderson-Hamilton volume): San Diego, Calif., Cordilleran Publishers, p. 441-447.

Howard, K.A., Stone, Paul, and Miller, C.F., 1989, Geologic map of the Milligan 15-minute quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2072, scale 1:62,500.

Hutton, D.H.W., 1979, Tectonic slides: A review and reappraisal: Earth Science Reviews, v. 15, p. 151-172.

John, B.E., 1981, Reconnaissance study of Mesozoic plutonic rocks in the Mojave Desert region, in Howard, K.A., Carr, M.D., and Miller, D.M., eds., Tectonic Framework of the Mojave and Sonoran Deserts, California and Arizona: U.S. Geological Survey, Open-File Report 81-503, p. 48-50.

Jones, J.A., 1973, Geology of the northern Kilbeck Hills and an adjacent portion of the Old Woman Mountains, eastern Mojave Desert, San Bernardino County, California: Los Angeles, Calif., University of Southern California, M.S. thesis.

Knoll, M.A., 1985, The early Miocene geologic history of the Old Woman Mountains area, eastern Mojave Desert, California: Nashville, Tenn., Vanderbilt University, M.S. thesis, 186 p.

Knoll, M.A., Miller, C.F., and James, W.C., 1986, Mid-Tertiary stratigraphic and structural evolution of the Piute Mountains and adjacent areas of the Old Woman Mountains region, southeastern California, in volume Trips 5 and 6--Cenozoic stratigraphy, structure, and mineralization in the Mojave Desert: Geological Society of America Annual Meeting, Cordilleran Section, 82nd, Los Angeles, Calif., March 25-28, 1986, Guidebook and volume, p. 43-49.

Kupfer, D.H., and Bassett, A.M., 1962, Geologic reconnaissance map of part of the southeastern Mojave Desert, California: U.S. Geological Survey Mineral Investigation Field Studies Map MF-205, scale 1:125,000.

Miller, C.F., Howard, K.A., and Hoisch, T.D., 1982, Mesozoic thrusting, metamorphism, and plutonism, Old Woman-Piute Range, southeastern California, in Frost, E.G. and Martin, D.L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada (Anderson-Hamilton volume): San Diego, Calif., Cordilleran Publishers, p. 561-581.

Miller, C.F., Wooden, J.L., Bennett, V., Wright, J.E., Solomon, G.C., and Hurst, R.W., in press, Petrogenesis of the composite peraluminous/metaluminous Old Woman-Piute Range batholith, southeastern California: Isotopic constraints, in Anderson, J.L., ed., Cordilleran magmatism: Geological Society of America memoir.

Miller, D.M. and Howard, K.A., 1985, Bedrock geologic map of the Iron Mountains quadrangle, San Bernardino and Riverside Counties, California: U. S. Geological Survey Miscellaneous Field Studies Map MF-1736, scale 1:62,500.

Miller, D.M., Howard, K.A., and Anderson, J.L., 1981, Mylonitic gneiss related to emplacement of a Cretaceous batholith, Iron Mountains, southern California, in Howard, K.A., Carr, M.D., and Miller, D.M., eds., Tectonic framework of the Mojave and Sonoran Deserts: U.S. Geological Survey Open-File Report 81-503, p. 73-75.

Miller, D.M., Howard, K.A., and John, B.E., 1982, Preliminary geology of the Bristol Lake region, Mojave Desert, California, in Cooper, J.T., compiler, Geologic excursions in the California Desert: Geological Society of America Annual Meeting, Cordilleran Section, 78th, Anaheim, Calif., April 19-21, 1982, p. 91-100.

Miller, W.J., 1944, Geology of the Palm Springs-Blythe strip, Riverside County, California: California Journal of Mines and Geology, v. 40, p. 11-72.

Moyle, W.R., Jr., 1967, Water wells and springs in Bristol, Broadwell, Cadiz, Danby, and Lavic Valleys and vicinity, San Bernardino and Riverside Counties, California: California Department of Water Resources, Bulletin 91-14, 17 p.

Reynolds, S.J., Spencer, J.E., and DeWitt, Ed., 1988, Stratigraphy and U-Th-Pb geochronology of Triassic and Jurassic rocks in west-central Arizona: Arizona Geological Society Digest, v. 18, p. 65-80.

Simpson, R.W., Bracken, R.E., and Stierman, D.J., 1984, Aeromagnetic, Bouguer gravity, and interpretation maps of the Sheep Hole-Cadiz Wilderness Study Area (CDCA-305), San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1615-B, 4 sheets, scale 1:62,500.

Spurk, W.H., 1959a, Geology and mineral resources of Township 4 North, Ranges 15 and 16 East, San Bernardino Meridian, San Bernardino County, California: San Francisco, Calif., Southern Pacific Land Company, unpublished map and report, scale 1:24,000.

----- 1959b, Geology and mineral resources of Township 2 North, Ranges 15 and 16 East, San Bernardino Meridian, San Bernardino County, California: San Francisco, Calif., Southern Pacific Land Company, unpublished map and report, scale 1:24,000.

Stone, Paul, Howard, K.A., and Hamilton, Warren, 1983, Correlation of metamorphosed Paleozoic strata of the southeastern Mojave Desert region, California and Arizona: Geological Society of America Bulletin, v. 94, p. 1135-1147.

Stone, Paul, Page, V.M., Hamilton, Warren, and Howard, K.A., 1987, Cretaceous age of the upper part of the McCoy Mountains formation, southeastern California and southwestern Arizona, and its tectonic significance: Reconciliation of paleobotanical and paleomagnetic evidence: Geology, v. 15, p. 561-564.

Streckeisen, A.L., 1973, Plutonic rocks classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks: Geotimes, v. 18, n. 10, p. 26-30.

U.S. Geological Survey, 1981, Aeromagnetic map of the Needles 1° x 2° quadrangle, California and Arizona: U.S. Geological Survey Open-File Report 81-85, scale 1:250,000.

Walker, J.D., 1987, Permian to Middle Triassic rocks of the Mojave Desert, in Dickinson, W.R., and Klute, M.A., Mesozoic rocks of southern Arizona and adjacent areas: Arizona Geological Society Digest, v. 18, p. 1-14.

Wright, J.E., Howard, K.A., and Anderson, J.L., 1987, Isotopic systematics of zircons from Late Cretaceous intrusive rocks, southeastern California: Implications for a vertically stratified crustal column [abs.]: Geological Society of America Abstracts with Programs, v. 19, p. 898.

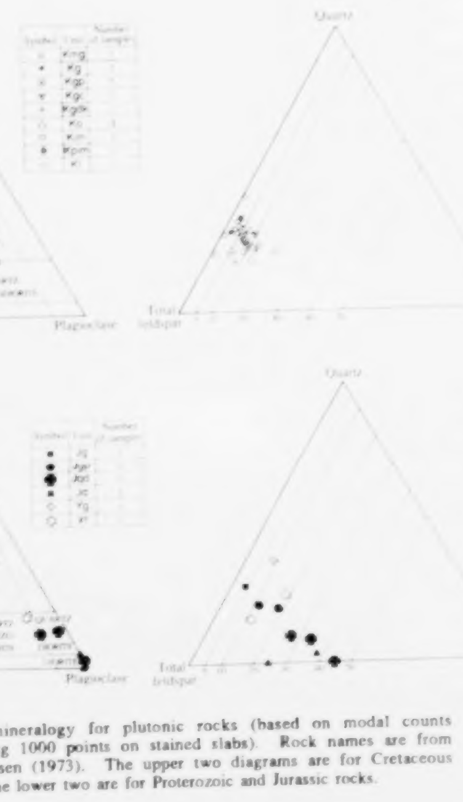


Figure 2. Modal mineralogy for plutonic rocks (based on modal counts averaging 1000 points on stained slabs). Rock names are from Streckeisen (1973). The upper two diagrams are for Cretaceous rocks; the lower two are for Proterozoic and Jurassic rocks.

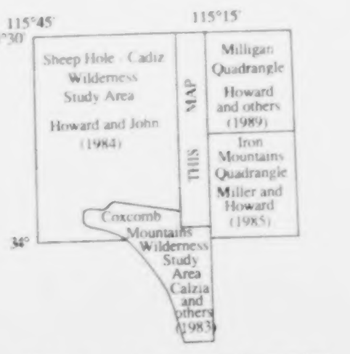


Figure 1. Index to geologic mapping.

GEOLOGIC MAP OF THE EASTERN PARTS OF THE CADIZ LAKE AND CADIZ VALLEY 15-MINUTE QUADRANGLES, SAN BERNARDINO AND RIVERSIDE COUNTIES, CALIFORNIA

By

Keith A. Howard, Eric D. Horringa, David M. Miller, and Paul Stone

1989

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DEPARTMENT OF THE INTERIOR
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VERTICAL SURFACE DISPLACEMENTS ALONG A PART OF THE NEWPORT-INGLEWOOD ZONE OF FOLDS AND FAULTS, LOS ANGELES AND ORANGE COUNTIES, CALIFORNIA

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